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Insulating coat to prevent mold growth in thermal bridges

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Abstract

Mold growth in buildings represents a widespread issue. It is, indeed, not only an aesthetic problem, but above all, a serious concern for the indoor air quality, which is directly related to the occupants' health.
Most of the existing residential buildings are poorly insulated and heavily affected by the presence of thermal bridges, that constitute the first area colonized by mold.
In this paper the mitigation of the thermal bridges impact by applying a fine layer of insulating rendering coat in the interior side was analyzed. The numerical analyses were focused on a typical thermal bridge occurring on the Italian building stock between a vertical wall and a concrete slab and were carried out through dynamic 2D Heat and Moisture Transfer simulations. Moreover, the results related to the surface temperatures and relative humidity were used for the calculation of the mold index by means of the VTT growth model.
Results are encouraging showing that the presence of the fine insulation rendering coat could moderately reduce the effect of the thermal bridges but can have a significant effect on the mold growth risk reduction.

Keywords: mold growth; thermal bridges; insulating rendering; heat and moisture simulations; indoor air quality.

1. Introduction

People spend around 90% of their time in indoor environments [1]. As a consequence, indoor air quality is of key importance to ensure occupants' well-being and overall comfort. Among the causes that most hamper the indoor air quality, dampness and molds are the most common and widespread.

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In this paper, an insulating rendering coat is applied on the inner surface of a building wall and ceiling chosen as case study. The main advantage of using this rendering coat is that very thin layers can be effective to increase the surface temperature, thus lowering the relative humidity and reducing the mold growth risk. The aim of this paper is to assess the effects of this insulating rendering coat, referring in particular on its impact on mold growth reduction.

In the following sections, first a literature review will be drawn; then the case study will be presented, along with the boundary conditions. The heat and moisture simulations and the mold growth analysis will be described. Later, results will be presented and critically discussed. Finally, the conclusions will be drawn with some hints on future perspectives.

Nomenclature

d	Thickness
λ	Thermal conductivity
φ	Relative humidity
ρ	bulk density
R	Thermal resistance
c	specific heat capacity
T	Temperature
b_{tr}	Adjustment factor of the temperature difference for unheated space
M	Mold index

Subscripts

i	internal space
e	external space
s	surface

2. Literature review

Both extrinsic and intrinsic factors, as defined by Blackburn [2], influence the mold growth. The extrinsic factors are related with the climate (air temperature, relative humidity), while the intrinsic factors depend on the characteristics of the building materials [3]. The insulating rendering coat aims at changing the extrinsic factors (increase surface temperature, decrease of relative humidity), in order to lower the mold growth risk.

Dampness and molds can occur in a variety of different scenarios: in the existing building stock, poorly insulated envelopes lead to low internal surface temperatures; in new constructions, highly air tight envelopes together with bad ventilation management cause high internal relative humidity. In refurbishment interventions, since the aim is to improve the energy performance of the envelope, poor insulation and moisture problems are usually solved, but linear or punctual thermal bridges often occur (especially in case of internal insulation), with the consequence of zones characterized by low temperatures and high relative humidity values [4].

In contrast with the fact that mold growth issues are widespread and of serious concern, little attention is paid in literature. On one hand, few studies among the many present on building envelopes provide evaluations on mold growth risk ([5], [6]). On the other hand, little attention is paid to provide feasible solutions. Thermal plasters have been deeply explored, in a variety of different combinations, which mainly included: natural and mineral-based insulating materials, in order to lower the plaster embodied energy ([7], [8]); innovative, responsive materials, such as PCM, in order to increase the envelope thermal inertia and reduce the temperature fluctuations over time [9]; super-insulating materials like aerogel, which is characterized by extremely low thermal conductivity ([10], [11]). Although thermal plasters can be seen as a valuable solution to dampness and mold, some problems can occur due to their not negligible thickness: a layer of about 40 to 80 mm of thermal plaster is usually needed to have significant effects. Therefore, inner space reduction occurs and invasive work is necessary.

3. Methods

The analyses were carried out through 2D dynamic numerical simulations of heat and moisture transfer in a typical existing building envelope affected by a thermal bridge between a vertical wall and a concrete slab. The results in terms of surface temperature and relative humidity (yearly time profile) were used to determine the reduction of the mold growth risk by applying a thin layer of a thermal insulation coat.

3.1. The case study

The selected case study represents the vast majority of the existing building stock in Italy (non-insulated residential building built between 1946-1976) [12], when energy regulations were not present. Most of these buildings are affected by mold growth. The intersection between the vertical wall and the non-insulated horizontal slab below the roof attic (Fig. 1) represents a particularly critical area for mold growth.

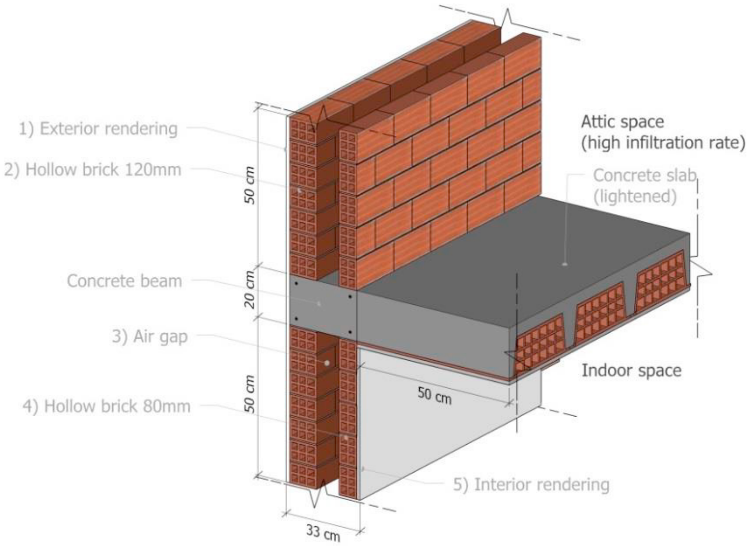

Fig. 1. 3D view of the analyzed node

Table 1. Vertical wall layers (physical properties)

layer	*material*	*d* (*mm*)	ρ (*kg/m*^{3})	c (*J/kgK*)	λ_{eq} (*W/mK*)	R (*m*^{2}*K/W*)
	Outdoor condition					0.04
1	Exterior rendering	20	1800	850	0.90	
2	Hollow clay brick 120mm	120	800	830	0.30	
3	Air gap	110	1.3	1050	-	0.18
4	Hollow clay brick 80mm	80	800	830	0.30	
5	Interior rendering	20	1400	850	0.70	
6	Insulating coat	6	627	820	0.14	
	Indoor condition					0.13

Table 2. Horizontal slab (physical properties)

layer	*material*	*d* (*mm*)	ρ (*kg/m³*)	c (*J/kgK*)	λ_{eq} (*W/mK*)	R (*m²K/W*)
	Unheated attic space					0.10
1	Concrete slab	200	1800	850	0.9	
5	Interior rendering	20	1400	850	0.70	
6	Insulating coat	6	627	820	0.14	
	Indoor condition					0.10

3.1.1. Boundary conditions

To simulate the external boundary conditions, Turin weather data (year 2004) was used, the solar radiation and driving rain effect were neglected, since it was assumed that the analyzed component is north oriented and it is placed below the roof overhang.

The indoor set-point temperatures were assumed of 20°C and 25°C for the heating and the cooling season respectively, while, for the relative humidity, a residential space with high moisture load condition was considered according to UNI EN 15026:2008

The temperature profile of the unheated attic space T_{attic} was determined using eq.1, while its relative humidity φ was assumed to be equal to the outdoor relative humidity φ_e.

$$T_{attic} = T_i - \frac{b_{tr}(T_i - T_e)}{T_i} \tag{1}$$

Where: b_{tr} is the adjustment factor of the temperature difference for unheated space (UNI EN ISO 13789:2001); in this specific case study b_{tr} was assumed to be equal to 0,9 (non-insulated roof), as suggested in UNI/TS 11300-1:2014.

3.2. Heat and moisture simulation

A coupled HAMS (Heat Air and Moisture Simulation) tool, Delphin 5.8.3. (Bauklimatik –Dresden), was used to perform the 2D dynamic numerical simulations, thus assessing the temperature and relative humidity profile in the investigated node (indoor intersection between wall and slab).

The software includes a sets of moisture mass balance equations (convective liquid water flux, convective water vapor flux and diffusive water vapor flux) and internal energy balance equations (heat conduction flow and total internal energy density), and solves the system of partial differential equations fully coupled. The numerical solution is achieved by semi-discretization in space (using a finite/control volume method) and subsequent integration in time [13].

The simulations were carried out with a 30 minutes time step, considering as initial conditions 13°C of surface temperature and 99% of relative humidity. The geometrical model was discretized in 1325 elements and a mesh refinement criteria with a minimum element width of 1mm was used in correspondence of the analyzed node (Fig. 2).

The simulations cycles were performed for 3 years, that are sufficient to reduce the RMSE (root mean square error) between the results of the second and the third year of simulation below 0.01°C, whit a maximum divergence of 0.15°C.

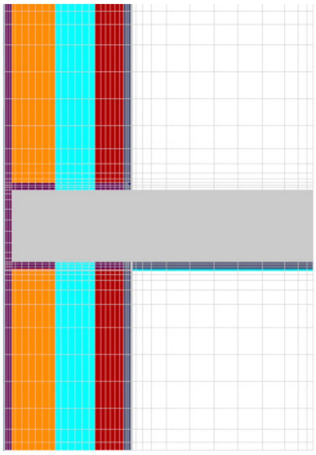

Fig. 2. Discretization of the 2D geometrical model

3.3. The mold growth analysis

Performing a mold growth analysis is of crucial importance to provide a complete picture of the Indoor Environmental Quality (IEQ). It allows to evaluate the risk of mold growth over time, enabling building designers to take actions aimed at solving potential issues that could lead to poor IEQ.

The VTT model was used in this study, due to the fact that its use is largely widespread and recognized in literature ([4][14]). Through the VTT model, developed by Hukka and Vittanen in the VTT Technical Research Centre of Finland ([15]), it is possible to assess the mold growth development through the mold index (M), which ranges between 0 (no mold growth) and 6 (Very heavy mold growth).

A dedicated tool in Delphin implements the VTT model equations. As input data, the surface temperature and relative humidity are needed, along with a set of boundary conditions related to the surface typology (from very sensitive to resistant to mold growth) and the decline rate.

The interface between the ceiling and the inner wall surface was chosen for the assessment of mold growth, since it was found to be the most critical in terms of surface temperature and relative humidity combination. Being the material properties as described above (Table 1 and Table 2), the surface typology was set as "Medium resistant", while the decline rate was set as "relatively low decline". Since it is not possible to know how long it is needed in order to obtain convergence in the mold index values, a time span of 20 years was chosen.

Two cases were assessed and compared: the "uncoated surface" case and the case in which a 6 mm of insulating rendering coat is applied. Therefore, two sets of surface temperature and relative humidity related to the same spot were considered, each for the two cases. Only the last year of the heat and moisture simulation results was considered. To perform the mold growth analysis, the last year results of the heat and moisture simulation were considered and cyclically for the entire time span (20 years).

4. Results

In the following sections, the results of temperature and relative humidity at the critical node are presented. Then a comparison between the uncoated node and the node coated with 6 mm of insulating coat was assessed in terms of surface temperature and relative humidity. The obtained results were then used to determine the mold growth index for the two analyzed nodes.

4.1. Heat and moisture simulation results

The isothermal profile calculated in the critical condition (Fig.3a) highlights the node characterized by the lowest temperature. For this critical node, the time series of surface temperature and relative humidity at the indoor surface are reported for one year of simulation in Fig.3b. It is interesting to observe that for almost all the winter period, the relative humidity at the node is φ = 100% (saturation condition of water vapor).

Moreover, in Table 3, the peak of lowest temperature and highest relative humidity at the node are reported for the two analyzed configurations. It is important to underline that the presence of the insulated rendering coat leads to an increase of ~1.5°C in the most critical spot of the node. Consequently, a reduction of relative humidity from 100% to 99.8% is observed, meaning that the dew point was never reached in the whole year of simulation.

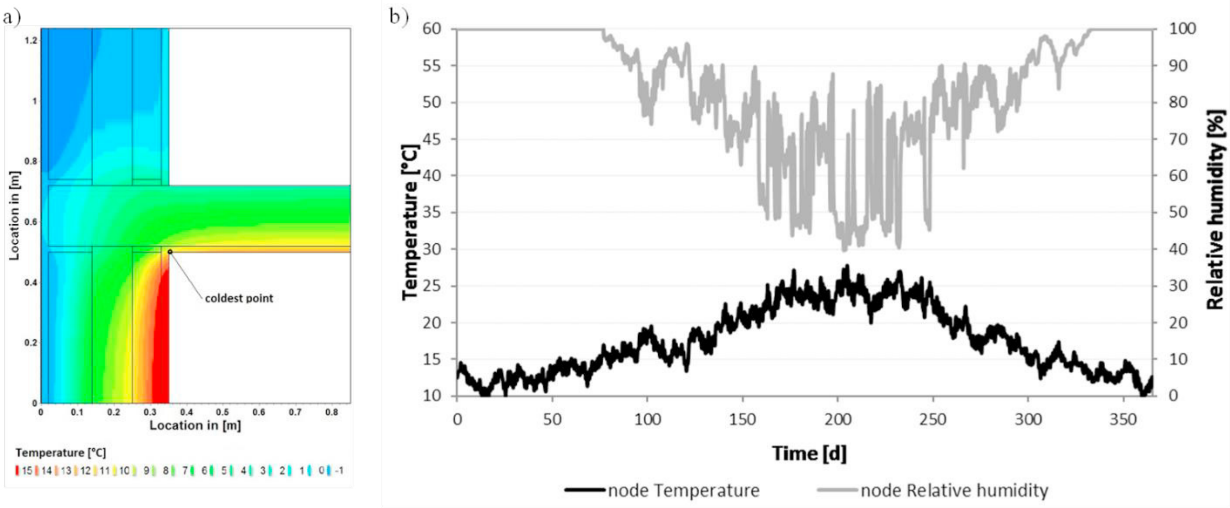

Fig. 3. (a) Isothermal profile for the uncoated surface; (b) Time series of temperature and relative humidity at the node for the uncoated surface.

Table 3. Peak values of temperature and relative humidity at the node surface

configuration	T_{min} (°C)	φ (%)
Uncoated node	9.3	100%
6mm of insulating coat	10.8	99.8%

4.2. The mold index

In Fig. 4 it is possible so observe the mold index as a function of time for both the “uncoated surface” case and the “6 mm of insulating rendering coat” one.

When both curves converge to stable values (around the 15th year), the mold index difference between the two cases is of about 0.6, which cannot be considered as a negligible value.

The most interesting observation, however, is that before reaching stable values, the mold index increases at very different rates in the two cases. It is in fact clear that the “uncoated surface case” stabilizes around the 7th year, while the “6 mm of insulating rendering coat” case around the 15th year (as stated above). This observation is of crucial importance because, as highlighted in Fig. 4, after a time span of 5 years, some maintenance works are usually carried out, restoring the initial mold conditions (*M=0*). Therefore, it is more useful to compare the two cases from the initial time to the “maintenance milestone”: mold index differences reach values up to 2. Between year 3 and 4, for example, the two cases are characterized by mold index values of respectively 1 and 2.7; *M=1* can be seen as borderline, but still acceptable, while *M=2.7* can lead to serious drawback in the occupants' health.

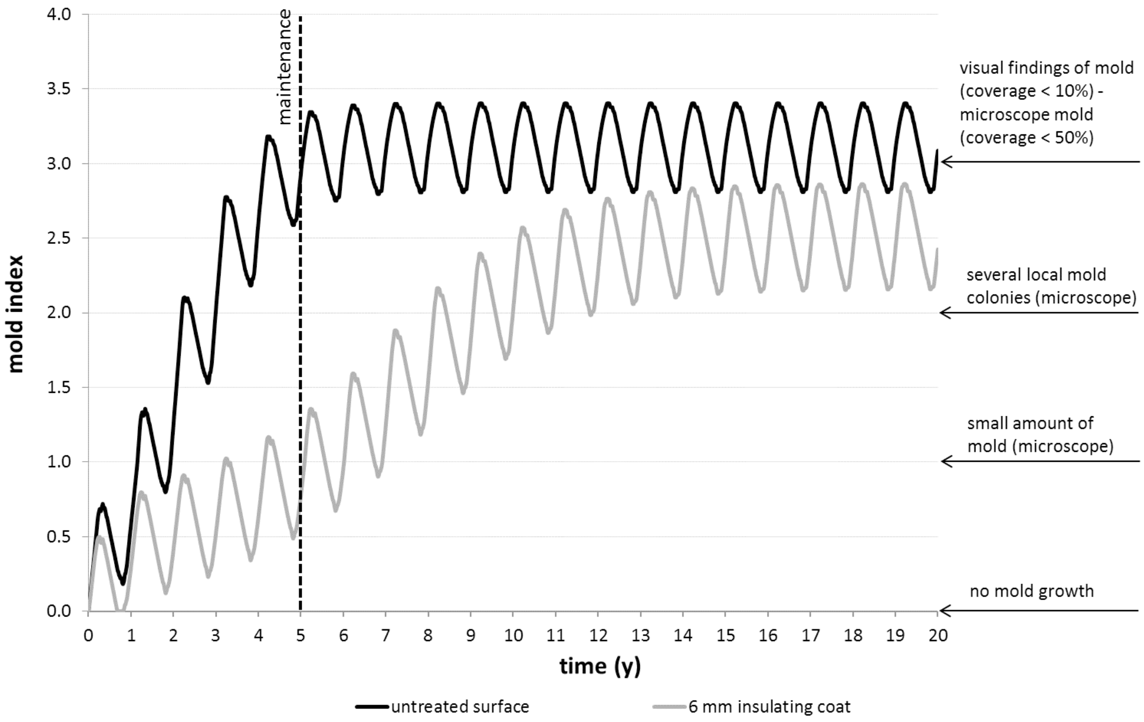

Fig. 4. Mold index (M).

5. Discussion

To investigate the advantage of using insulating coat, a comparison of the cumulated frequency distribution of temperature (Fig.5a) and relative humidity (Fig.5b) are presented (the analyses were focused only on the ranges of critical low temperature and high relative humidity). Results on the uncoated surface demonstrate that for ~8% of the time, the temperature is lower than 12°C (dew point for φ = 60%). The presence of 6 mm of insulating coat determines a sensible mitigation of the critical conditions, in fact only ~2.5% of the time the temperature is lower than 12°C (Fig.5a). In addition, Fig 4b present a not negligible reduction of the relative humidity conditions: φ > 99% are reached for 30% of the time for the uncoated surface and 10% for the coated surface.

Moreover the analysis on the mold index demonstrate that the 6 mm of insulating rendering coat surface treatment, not only lead to lower absolute values of mold index (therefore lower mold growth), but also slow down the process, allowing the occupants to live in a healthier environment for a longer time, keeping in mind that maintenance works are anyway needed to restore the initial conditions.

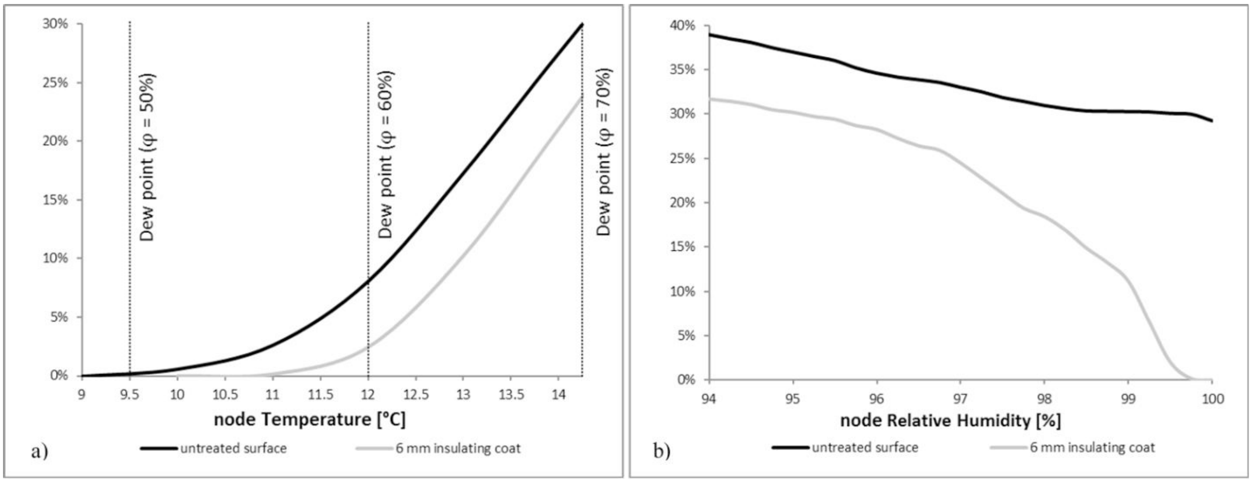

Fig. 5. Cumulative frequency distributions at the analyzed node (a) temperature; (b) relative humidity.

6. Conclusions

In this study, HMT simulations were performed to assess the mold growth in a typical building thermal bridge. The uncoated surface case was compared to a refurbishment case, in which 6 mm of insulating rendering coat is applied. Results show that even a thin layer of insulating rendering coat can be effective to reduce mold growth.

The above described results, in fact, demonstrate that the presence of the insulating coat allows to prevent surface condensation: in the uncoated case, wall condensation occurred for about 30% of the time, while no condensation was found in the coated surface. This heavily influences the mold growth rate, given the mold need of high humidity environments to grow.

After 5 years, which was considered to be a reasonable time span for maintenance purposes, the mold index is about 3 and 1 in the uncoated surface case and the 6 mm of insulating rendering coat case respectively. This difference is considerably high, since for a mold index equal to 3, macroscopic mold is visible, with aesthetics and occupants' health drawbacks, while a mold index equal to 1 has negligible impact on occupants' health and does not lead to visual (thus aesthetic) issues.

To conclude, insulating rendering coat can be seen as a valuable solution to mold growth problems in building thermal bridges, because of the high feasibility and effectiveness. Further studies can be carried out to assess the influence of the insulating coat thickness on the mold growth reduction. Moreover, new insulating materials such as aerogel can be added to the rendering coat mixture, in order to make the rendering coat even more effective by further reducing its thermal transmittance.

References

[1] WHO. Combined or multiple exposure to health stressors in indoor built environments - An evidence-based review prepared for the WHO training workshop "Multiple environmental exposures and risks."; 2014; 88.
[2] Blackburn CDW. 3 - Modelling shelf-life, In Woodhead Publishing Series in Food Science, Technology and Nutrition, Woodhead Publishing, The Stability and Shelf-Life of Food; 2000;55-78.
[3] Johansson P. Critical Moisture Conditions for Mould Growth on Building Materials. Rapport TVBH-3051 Lund Avdelningen fӧr Byggnadsfysik, LTH; 2012.
[4] Vereecken E, Roels S. Review of mould prediction models and their influence on mould risk evaluation. Build Environ; 2012;51:296–310.
[5] Harrestrup M, Svendsen S. Internal insulation applied in heritage multi-storey buildings with wooden beams embedded in solid masonry brick façades. Build Environ; 2016;99:59–72.
[6] Alev Ü, Kalamees T. Avoiding mould growth in an interiorly insulated log wall. Build Environ. 2016;105:104–15.

[7] Carbonaro C, Tedesco S, Thiebat F, Fantucci S, Serra V, Dutto M. An integrated design approach to the development of a vegetal-based thermal plaster for the energy retrofit of buildings. Energy Build; 2016;124:46–59.
[8] Bianco L, Serra V, Fantucci S, Dutto M, Massolino M. Thermal insulating plaster as a solution for refurbishing historic building envelopes: First experimental results. Energy Build; 2015;95:86–91.
[9] Carbonaro C, Cascone Y, Fantucci S, Serra V, Perino M, Dutto M. Energy assessment of a PCM-embedded plaster: Embodied energy versus operational energy. Energy Procedia; 2015;78:3210–5.
[10] Ghazi Wakili K, Stahl T, Heiduk E, Schuss M, Vonbank R, Pont U, et al. High performance aerogel containing plaster for historic buildings with structured façades. Energy Procedia; 2015;78(0):949–54.
[11] Galliano R, Ghazi Wakili K, Stahl T, Binder B, Daniotti B. Performance evaluation of aerogel-based and perlite-based prototyped insulations for internal thermal retrofitting: HMT model validation by monitoring at demo scale. Energy Build; 2016;126:275–86.
[12] Istat. L'Italia in 150 anni. Sommario di statistiche storiche 1861-2010. Capitolo 15: Abitazioni e costruzioni; 2011;691-708.
[13] Nicolai A, Grunewald J. Delphin 5 - Version 5.8.3, User Manual and Program Reference. 2015.
[14] Vereecken E, Vanoirbeek K, Roels S. A preliminary evaluation of mould prediction models based on laboratory experiments. Energy Procedia; 2015;78:1407–12.
[15] Hukka A, Viitanen H. A mathematical model of mould growth on wooden material. Wood Sci Technol. 1999;33:475–85.